Sandia National Laboratories

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SUMMARY REPORT FOR

UTILITY EXPERIENCE WITH HIGH PENETRATION PV WORKSHOP

HOSTED BY:

EUROPEAN DISTRIBUTION ENERGIES RESEARCH LABORATORY (DERLAB)

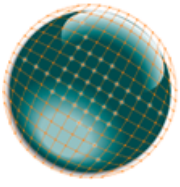
ELECTRIC POWER RESEARCH INSTITUTE (EPRI)

SANDIA NATIONAL LABORATORIES

AT

THE 5TH INTERNATIONAL CONFERENCE ON INTEGRATION OF RENEWABLE AND DISTRIBUTED ENERGY RESOURCES

BERLIN, GERMANY | DECEMBER 2012



5th International Conference on
Integration of
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REPORT PREPARED BY: SANDIA NATIONAL LABORATORIES

Utility Experience with High Penetration PV

Workshop Summary

Monday, December 3 | 8:00 a.m. – 12:00 p.m.

As solar photovoltaic (PV) deployments grow in number and size, distributed electricity networks worldwide operate with increasing levels of PV penetration. Sharing the technical expertise, best practices, and lessons learned from operating distributed systems under high PV penetration is critical to the successful advancement of PV as an electricity source.

*The **Utility Experience with High Penetration PV Workshop** convened solar PV researchers, grid integration and electricity distribution experts, and utility representatives to discuss experience with high PV generation levels in a number of countries with varying levels of solar. The session highlighted technical successes and challenges, regulations, and the technological implications of evolving grid codes. The objective of the High Penetration PV Workshop was to foster an international community of practice within which participants can learn and collaborate. Organizers also hoped to more deeply engage utilities in the codes and standards process, encouraging and enabling them to contribute to standards that address key barriers to high penetration of PV. The workshop was co-hosted by Sandia National Laboratories, Electric Power Research Institute (EPRI) and European Distributed Energies Research Laboratories (DERlab).*

U.S. Experience with High Penetration PV - Jeff Smith, Manager Power Systems Studies, EPRI

- EPRI is doing research on impacts of high penetration PV based on sites with thousands of actual feeders. Circuits vary widely in terms of design (length, number of regulators, etc.) and loading level.
- Voltage effects from PV can vary greatly depending on distribution circuit design and size/location of DG interconnections; e.g., customer-sited PV can result in over-voltages and impacts the customer directly if local penetration levels are high enough
- Smart inverters with grid control can significantly improve integration of high PV penetration; need to address conflicts between grid support functions and active anti-islanding functions
- Need standards for smart inverter implementation, consensus on standard functions, and improved screening for new interconnections

PV in Italy and Integration Challenges for ENEL - Gianluca Gigliucci, Enel Ingegneria e Ricerca S.p.A, Pisa, Italy *(Note: Gianluca presented a summary of the material he presented at the IRED conference on December 4th. The link is included here for completeness).*

- Substantial rise of renewable energy share (15.5 GW of PV, 6.5 GW of wind) having a great impact on the way energy is managed
- Continuous match of power availability and load requires higher flexibility and smarter electric systems
- Impacts at the transmission and distribution levels; e.g., some transformers seeing reverse power flow
- Impact on conventional generation: reduction of capacity factor, dynamic operation required, increase of part load operation
- Reaction to the impacts: New requirements for DG connection and new incentives/penalties. Developing advanced Distribution network Management System (DMS); to be implemented in June 2013 for six months of field testing

International Grid Codes and Local Requirements – the Evolvement of Standards for Distributed Energy Resources and Inverter Technology - Hannes Knopf, Director of International Product Management, SMA Solar Technology AG

- International standards exist, but are often adjusted or augmented by national/regional standards addressing specific features such as geography, installed renewable power vs. installed total power, grid structure
- Focus in Europe varies but centers primarily on geography/cross-border interconnects and classification of generators
- Recently, a major effort was made to update DG grid codes and actually retrofit fielded inverters to address the 50.2-Hz problem resulting from the large amount of distributed PV deployed in Germany and Italy over the last two to three years. This exemplifies the need to adapt grid codes for high penetration scenarios.
- Draft network code *Requirements for Grid Connection Applicable to All Generators* in development by European Network

of Transmission System Operators for Electricity (ENTSO-E) provides legal framework for local grid codes and focuses on cross-border issues, but *does not* replace local codes or result in European harmonization
- Focus in Japan is on islanding detection; other grid interconnection provisions such as frequency voltage and frequency tolerance are not yet required
- Harmonized requirements and reasonable transition time are essential to sustainable growth of PV

PV Interconnection in the US: IEEE 1547 Status and Outlook – Abraham Ellis, Sandia National Laboratories (co-author: Tom McDermott, University of Pittsburgh)
- Must-trip provisions and voltage control prohibition written into the current IEEE 1547 standard are considered barriers for high penetration of PV in North America. In high penetration PV scenarios, voltage and frequency ride-through is needed to preserve system stability, while volt/var capability is needed to allow PV to self-mitigate local voltage impacts and reduce interconnection cost.
- IEEE P1547a – Proposed fast track amendment to IEEE 1547 (Fall 2013 ballot); updates provisions related to voltage regulation and DR response to abnormal voltage and frequency levels; provides for DR to actively regulate voltage *in coordination with* the Area EPS operator.
- 1547.8 – Recommended Practice for Establishing Methods and Procedures that Provide Supplemental Support for Implementation Strategies for Expanded Use of IEEE Standard 1547: Does not affect the **standard**, but addresses active voltage regulation and other factors; group working to harmonize with P1547a before ballot
- To pass first ballot, P1547a must be better structured to accommodate synchronous generators, other DR technologies, and cases relying on voltage drop for fault protection

Technology for high penetration PV systems on a distribution line in Japan – Yusuke Miyamoto, Kandenko
- Japan target is 53 GW of PV by 2030 (will require 70% of new residences to install solar); Japanese grid permits systems <2 MW to be connected to middle voltage distribution line
- Feed-in tariff available on government-certified PV systems in two levels: <10 kW and >= 10 kW; has had demonstrated positive effect on number of PV systems installed
- Primary technical challenges to high penetration PV in Japan are islanding detection and fault ride-through
- Japanese Standardized Islanding Detection Function (JSIDF) developed by NEDO; JSIDF islanding detection function required for all Japanese inverters since 2011
- Technical solution to address voltage increases is based on PV output reduction; also considering voltage regulation devices on feeders and possibly reactive power capability from inverters.

DERlab member institutes' capabilities related to inverters technology, grid codes, and standards – Dominik Geibel, Fraunhofer IWES
- DERlab primary business areas: electrical testing of DER components; testing of DER systems and power system services from distributed units; and communications and IT security
- Europe is subject to several TDO/DSO, national and regional standards (grid codes), testing guidelines, and certification procedures
- Units (inverters) are required to be certified for grid behavior and model validation. FGW certification guidelines are ground-breaking for international standardization of WTG; now applicable to other DER (PV, biomass, etc,).
- Working group convened to adapt testing guidelines specifically for PV, chaired by Fraunhofer. Steps to adapt include:
  - **PV-Specific:** independent testing of solar modules, testing of network faults at LV level (LVRT)
  - **General Measurement:** power acquisition/voltages and currents; synchronous measurement of power and set-point signals; RS485 signals from PC to PV inverter using programmable logic
- Though testing methods need to be adapted to specific DER units, testing is essential to development of grid codes

Inverters to provide grid support (DG and Storage) – Tom Key, EPRI (presentation co-author: Brian Seal, EPRI)
- Inverters with smart grid capacity can double DER capacity on the grid, but proprietary manufacturer protocols and grid limitations prevent integration of such inverters at a high level
- Smart DER Communication Initiative provides foundation for field testing; 20 common inverter functions collaboratively identified; standards developed address smart volt-var curves, individual device status/state monitoring, connect/disconnect control, load/generation smoothing, and other functions
- Focus on transforming individual DER functions (capability) into useful enterprise services at the system level
- Target to host interoperability demonstration event in Q3 2013

Key Findings

Utility Experience with High Penetration PV Workshop

- There is a general perception that Europe's higher levels of renewable energy penetration mean that European countries are aligned in their standards and approach to RE. However, although ENTSO-E's *Requirements for Grid Connection Applicable to All Generators* attempts to harmonize various codes, there is no single standard that applies. Cross-border coordination of RE standards, testing, and certification is still lacking in Europe and navigating all the requirements continues to be a challenge overall.

- Technical issues associated with high levels of PV and other renewables do not differ significantly from country to country. While specific details may vary depending on circuit design characteristics, most challenges are associated with voltage and frequency effects, islanding, and fault detection. The technical commonalities of these challenges can be identified through international collaboration, and such collaboration could in turn help ensure development of globally-accepted and better harmonized standards.

- Laboratory testing by independent facilities could prove invaluable in the establishment of globally-accepted standards for high RE penetration. By providing third-party input on fault detection, power management, general interconnection requirements, and other critical factors, such facilities can help identify and bridge differences in the standards. The inclusion of such testing – and the standardization of the testing itself - should be a central tenet in the development of long-term strategies to achieve high penetration PV.

- The current level at which utilities participate in the codes and standards process appears to be relatively low in most countries. Encouraging (or even requiring) utilities to engage on standards development increases the chance that codes will better address relevant field issues and more easily achieve industry buy-in. However, some standardization and alignment on PV (and other DG) grid support functions and interoperability will be necessary before this increased participation can be effectively executed. Otherwise, each utility and manufacturer will likely lobby for codes that best support their unique systems, designs, and components, which could slow or even deadlock the process.

- The process of developing or updating codes and standards is relatively slow due to the consensus process, and there is no standard approach to address technology differences. Several European grid codes acknowledge technology differences (inverters vs. rotating machines), but other standards like IEEE 1547 are technology neutral. Revamping the procedures for standards development may be necessary to align with demands for increasing levels of PV. Achieving this may require component and design standardization, and/or a more effective approach for addressing technology differences.

- Advanced inverters have the ability to mitigate impacts on distribution systems, particularly voltage. The use of advanced inverters would also be less expensive than current approaches for mitigating integration issues, such as grid upgrades or the addition of voltage management. However, current standards don't account for or require these advanced technologies. This in turn reduces options available in the marketplace, because inverter manufacturers are reluctant to add advanced functions that aren't required. Given increased understanding about the potential benefits and cost savings of advanced inverters, the lack of standards for these technologies needs to be addressed.

Workshop Agenda: Utility Experience with High Penetration PV

Hosted by DERLab, Electric Power Research Institute, and Sandia National Laboratories
Monday, December 3, 2012
MARITIM proArte Hotel – Salon 2

Solar photovoltaic (PV) generation continues to be deployed in large quantities in many parts of the world. A growing number of distribution networks are operating with very high PV generation levels. As a result, some system operators have acquired and institutionalized valuable technical experience and know-how. Sharing of these experiences can catalyze widespread adoption of best practices, provided that differences in system configuration, operating practices, interconnection requirements and regulatory environments are taken into account. This workshop will focus on utility operations experience with high PV generation levels.

8:00 – 8:10 Welcome and Introductions (Philipp Strauss, DERlab)

8:10 – 8:20 Brief Introduction and Background for the Workshop Topic (Abraham Ellis, Sandia National Laboratories, and Tom Key, Electric Power Research Institute [EPRI])

Session 1 Utility Operations Experience with PV in Distribution Systems

Moderator: Charles Hanley, Sandia National Laboratories

- *How much PV deployment has it been possible to achieve in the low voltage network?*
- *What are the main technical challenges: protection, voltage control, or other things?*
- *How are challenges being addressed? What is missing?*
- *What new technical challenges need to be considered to achieve even higher share of PV?*
- *What are the differences in solar policy or other factors that have enabled high penetration of PV in Europe vs. the lower penetration rates in the United States?*

8:20 – 8:40 Grid Integration of Renewable Energy: Experience from Germany (Remigiusz Pluciennik, E.ON edis AG)

8:40 – 9:00 PV Deployment in Distribution Systems: Experience from Italy (Gianluca Gigliucci, Enel Group, Italy)

9:00 – 9:20 High Penetration PV in North America (Jeff Smith, EPRI)

9:20 – 9:40 *Panel Discussion*

9:40 – 10:00 Break

Session 2 Grid Codes and Inverter Technology

Moderator: Roland Bründlinger, DERlab

- *How have grid codes evolved in light of high penetration PV on distribution circuits?*
- *What are the areas of concern with existing grid codes? What is missing or needs to change to accommodate future high PV levels?*
- *How is inverter capability evolving to meet interconnection requirements?*

10:00 – 10:20 Survey of LV/MV Grid Codes in Europe and Asia (Hannes Knopf, SMA Solar Technology)

10:20 – 10:40 Interconnection Requirements in the United States: IEEE 1547 (Abraham Ellis, Sandia National Laboratories)

10:40 – 11:00 Technology for High Penetration Residential PV Systems on a Distribution Line in Japan (Yusuke Miyamoto, Kandenko Co. Ltd.)

11:00 – 11:20 Technology Implications of Grid Codes (Dominik Geibel, Fraunhofer IWES)

11:20 – 11:40 *Panel Discussion*

11:40 – 12:00 **Summary of Key Points and Challenges (Charles Hanley, Sandia National Laboratories, and *Roland* Bründlinger, DERlab)**

- *Are there common challenges, gaps and lessons learned identified by presenters?*
- *Does technical cross-pollination among stakeholders from different countries help bridge the gaps and accelerate adoption of best practices? How can knowledge-sharing and interaction be increased?*
- *What is the potential role of utilities?*